Cook Inlet Basin

NAWQA News

National Water-Quality Assessment Program

Status Report, Summer–Fall 2001

What is NAWQA?

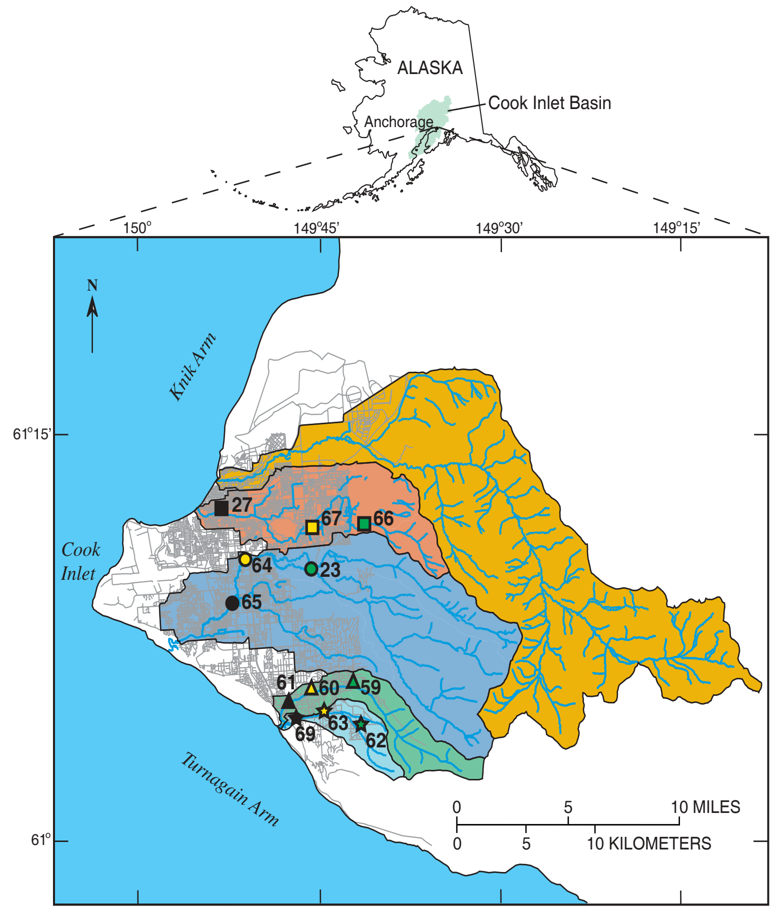
The Cook Inlet Basin in south-central Alaska (see map) is one of about 60 National Water-Quality Assessment (NAWQA) study units designed to assess the status and trends of the Nation's water quality. This program integrates the monitoring of surface- and ground-water chemistry with the study of aquatic ecosystems. The Cook Inlet Basin study began in 1997.

How has the NAWQA study addressed urbanization in the Cook Inlet Basin?

In 1999, we initiated a study to examine the issues associated with the impacts on water quality related to the amount of urban area within the Municipality of Anchorage. In the summer of 2000, data were collected from 12 sites (subbasins) in four stream basins in the municipality (see map, to the right). We compared the response of water chemistry, stream habitat, invertebrate communities, and land use to a gradient of urbanization as related to the percentage of impervious area (PIA), including streets, parking lots, houses, etc., upstream from each site. Impervious area in Anchorage was calculated by using high-resolution satellite images to differentiate between vegetated and unvegetated areas.

What is urbanization and how does it affect streams?

According to the U.S. Census Bureau, an urban area is defined as an area having a population density greater than 1,000 persons per square mile. For our summer of 2000 study, we calculated the PIA in a watershed upstream from a site as a measure of urbanization (see table on next page). Impervious area and population density have been shown to be highly correlated measures. We chose PIA to be a substitute for urbanization as it easily reflects changes in the landscape associated with development. Areas where rainfall or snowmelt cannot percolate into the ground have a direct effect on adjacent streams. In urban settings, runoff from precipitation carries fine sediments and pollutants washed from streets into storm drains that then drain into streams. Therefore, a locality that has a higher PIA delivers more "dirty" water to streams. The rapid delivery of water to the stream causes an unnaturally rapid rise in the water level within the stream (see hydrographs on next page). The water is also typically turbid or muddy in appearance, as streets are washed of sediments, trash, and pollutants. Under natural conditions (no human-induced impervious areas), water levels



EXPLANATION

Subbasins within Cook Inlet Basin:

Ship Creek
Campbell Creek
Little Rabbit Ceek
Chester Creek
Rabbit Creek

Sampling site (and site number):

Upstream	Middle	Downstream	
66 ■	67 □	27 ■	Chester Creek
23 ●	64 ○	65 ●	Campbell Creek
59 ▲	60 △	61 ▲	Rabbit Creek
62 ★	63 ☆	69 ★	Little Rabbit Creek

Description of sites

[PIA, percentage impervious area]

Site number used on map (ordered by PIA)	USGS station ID number and description	Elevation (feet)	Upstream watershed area (square miles)	Flow (cubic feet per second)	Specific conductance (microsiemens per centimeter at 25°C)	pH (standard units)	Temperature (degrees Celsius)	Dissolved oxygen (milligrams per liter)	Road density (miles per square mile)	Population density (number of people per square mile)	Storm-drainage density (miles of storm sewers per square mile)	PIA
66	15274796 South Branch of South Fork Chester Creek at Tank Trail.	358	4.3	3.4	113	8.2	4.5	11.4	0	0	0	0.0
23	15274000 South Fork Campbell Creek	233	29.2	58	72	7.7	4	12.7	.33	9	0	.3
59	15273020 Rabbit Creek at Hillside Drive	876	9.8	30	86	7.3	3.5	12.2	.98	32	0	.4
62	15273090 Little Rabbit Creek at Nickleen Street	1,230	2.6	6.2	109	7.7	1	12.6	2.12	60	0	1.2
63	15273097 Little Rabbit Creek at Goldenview Drive	590	5.6	15	128	7.9	2.5	12.8	4.2	125	0	3.4
64	15274395 Campbell Creek at New Seward Highway	98	45.9	78	84	7.6	5	11.6	.89	176	.45	3.7
60	15273030 Rabbit Creek at East 140th Avenue	436	11.3	28	90	7.6	6	12.5	2.97	136	0	7.5
61	15273040 Rabbit Creek at Porcupine Trail	121	13.3	34	96	7.6	6	12.2	4.04	262	0	8.1
69	15273100 Little Rabbit Creek	92	6.4	15	137	7.9	3	12.4	4.77	182	0	8.5
67	15274830 South Branch of South Fork Chester Creek at Boniface Parkway.	197	14.8	12	168	7.7	8	11.7	4.14	1,222	3.22	10.6
65	15274557 Campbell Creek at C Street	52	65.7	89	92	7.9	8	8.9	3.55	662	1.59	20.6
27	15275100 Chester Creek at Arctic Boulevard	16	27.3	31	242	8.1	11.5	10.4	9.24	2,736	6.95	39.9

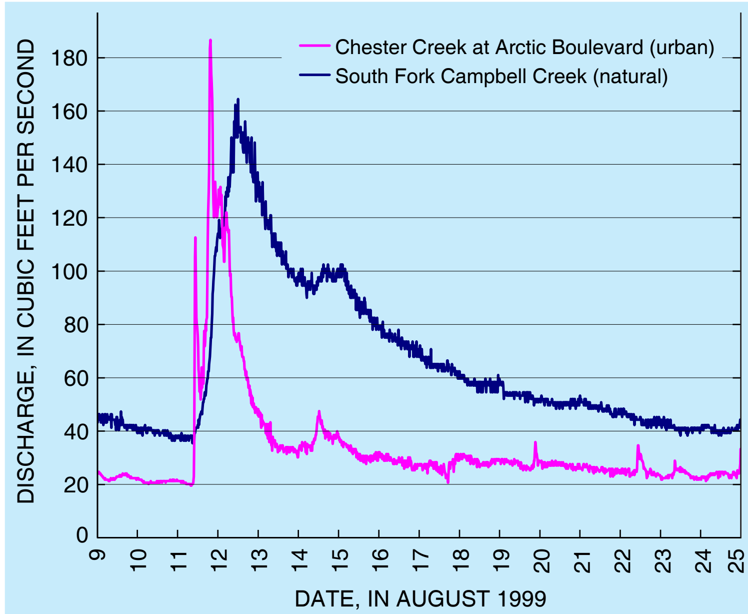
rise at a much slower rate, do not peak at as high a level, and are generally not as turbid (compare hydrograph of urban to natural stream).

How is water chemistry affected by urbanization?

Rainfall and snowmelt dissolve or suspend chemicals from impervious areas and carry them in runoff to streams. This chemical load generally can be related to specific conductance, a measure of the electrical conductivity of water. In the Anchorage area, the specific conductance values increased significantly with increasing PIA, thereby indicating that more dissolved chemicals are being transported in water from high-PIA areas. This, in turn, indicates that the amount of dissolved chemicals in the water has increased significantly with urbanization.

Does impervious area impact instream habitat?

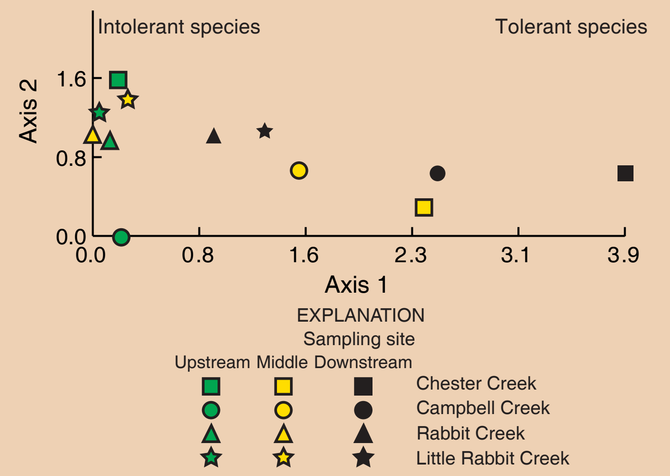
Many instream-habitat characteristics for each stream reach were measured during the summer of 2000. Variables included channel width, bank height, percentage of the substrate that is embedded (or degree to which larger particles are surrounded or covered by sand), particle size, stream depths, flow velocities, as well as many others. In our analysis, three of the habitat variables (percentage of reach exceeding 20 percent embedded substrate, stream sinuosity, and stream gradient) correlated significantly with impervious area. The riparian or streamside areas in Anchorage are generally intact wooded areas. Intact riparian areas have been shown to act as buffers or filters between a stream and human development. Riparian zones also provide an area for the stream to maintain an equilibrium between erosion and deposition: The channel cross section remains stable, but the actual position of the stream is allowed to meander or move around naturally. Instream habitat does not appear to be impacted negatively by the influences of the surrounding impervious area until the PIA exceeds approximately 3 percent, whereupon fine sediments begin to accumulate on the streambed. These sediments tend to displace invertebrates and small fishes that normally reside in the spaces between gravel and cobbles, thereby potentially decreasing the diversity of aquatic life in that area.



Hydrographs for a natural stream compared to an urban stream in the Cook Inlet Basin

How do invertebrates respond to urbanization?

The invertebrate communities found in the streams in Anchorage show a well-defined gradient related to tolerance or intolerance of human-induced disturbance. Certain groups of aquatic invertebrates (for example, mayflies, stoneflies, and caddisflies) are known to be sensitive to pollution and habitat modification. Others (for example, worms) commonly tolerate perturbations caused by human activities. The graph (top of next page) shows the intolerance-tolerance gradient of communities as one goes from areas of lower PIA (left side of graph) to areas of higher PIA (right side). Those sites grouping to the left had higher relative abundances of sensitive or intolerant species than did sites of high imperviousness (right side), which were dominated increasingly by insensitive or tolerant species. Generally, upstream, undeveloped subbasins were characterized by organisms intolerant to disturbance. Moving downstream to the middle subbasins revealed the initiation of changes to the community structure: Greater numbers of tolerant organisms and

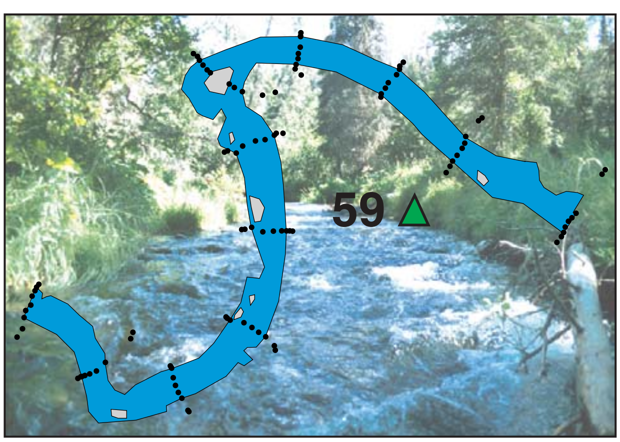


Gradient analysis of sampling sites in four subbasins in the Cook Inlet Basin

fewer intolerant organisms were generally observed. All downstream sites exhibited a complete shift in the overall community structure, as the most dominant groups of invertebrates were composed of tolerant species. Areas having more tolerant species were generally found to have lower water quality than those sites dominated by intolerant species.

How do urbanization and land use relate?

Land use also exhibited a gradient with respect to impervious area, although it was not as distinct as that shown by the invertebrate communities. Most of the sites having low PIA typically are dominated by residential land use and transportation right-of-ways or generally are undeveloped. The residential areas in Anchorage, as in many areas, have yards and green space associated with the developments. Many of the newer residential developments place a premium on yard size, thereby decreasing the PIA in much of the area associated with the upstream or hillside neighborhoods. The desire for more open space and modern planning also has the effect of decreasing the density of roads in the area. On the opposite end of the gradient, in the older, more densely developed areas in the lower parts of Chester Creek and Campbell Creek basins, we found the dominant factors relating to impervious area at the sites were primarily increases in transportation right-of-ways (roads and medians) and, to a lesser extent, increases in commercial and institutional land uses. Sites having high road densities (greater than 3 miles per square mile; see table, left page) generally were associated with a higher PIA.



Rabbit Creek (upstream reach)

Are there thresholds of impervious area at which the natural functioning of the stream is compromised?

The idea of a threshold value (a value at which a change in response is noted) for a particular variable or set of variables is attractive to planners, land managers, and others concerned with the impact of development on the natural surroundings. We examined each of the variables that correlated significantly with PIA and analyzed them for thresholds or breakpoints in the responses. Of the 10 variables significantly correlated with impervious area (see table, below), 6 exhibited a threshold. Water-chemistry analyses produced one response variable exhibiting a threshold at PIA values in the range 7.5 to 8.1 percent. Two response variables related to the invertebrate analyses had threshold responses at PIA values in the range 1.2 to 3.4 percent. Three habitat variables exhibited threshold values ranging from 0.4 to 3.4 percent.

Response variables that significantly correlated with percentage impervious area

[EPT, Ephemeroptera–Plecoptera–Trichoptera (mayflies, stoneflies, caddisflies). —, no break]

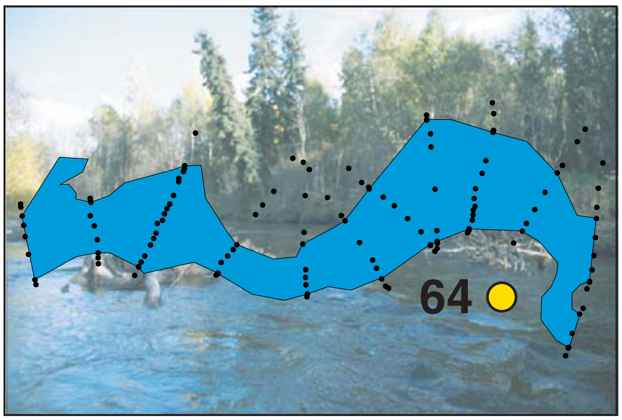
Response variable	Response threshold evident?	Range of impervious-area threshold (incremental percent)
Water chemistry		
Manganese concentration	Yes	7.5–8.1
Sodium concentration	No	—
Chloride concentration	No	—
Invertebrates		
Family biotic index	No	—
Percentage of shredders	No	—
Total taxa richness (family level)	Yes	1.2–3.4
EPT taxa richness	Yes	1.2–3.4
Habitat		
Percentage of reach exceeding 20 percent embedded substrate.	Yes	3.4–3.7
Stream sinuosity	Yes	0.4–1.2
Stream gradient	Yes	1.2–3.4

What are the implications?

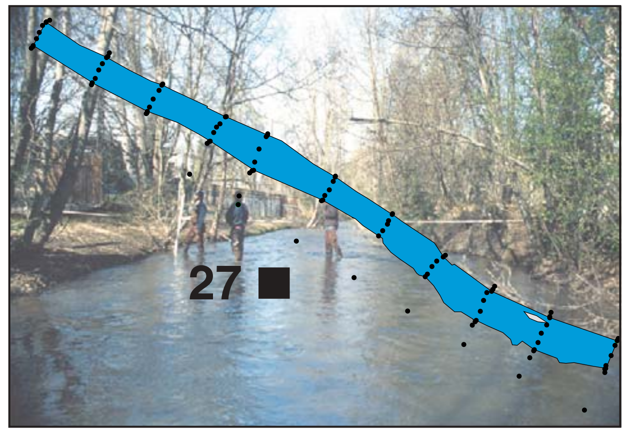
Water-chemistry, habitat, and invertebrate-community variables show a gradient of disturbance related to PIA values upstream from a sampling site. Threshold responses were found in about two-thirds of the significant variables examined in this investigation. This suggests that there is a point at which the stream has lost the ability to function naturally. Evidence further suggests that Anchorage streams became degraded at PIA levels as low as 3 to 4 percent, far lower than the reported range of 10 to 20 percent for municipalities in the lower 48 States.

Little Rabbit Creek appears to be the most affected of the four basins, as thresholds have been exceeded in all of its subbasins. The PIA associated with the most upstream subbasin (62) was higher than the thresholds in two habitat and two invertebrate variables. The Rabbit Creek basin appears to be on the verge of habitat and invertebrate thresholds in the upstream subbasin, and thresholds have been exceeded in the middle and downstream subbasins. Both of the two most highly developed subbasins, Campbell Creek and Chester Creek, have basically undeveloped upstream subbasins (23, 66). In comparison with the other middle subbasins, Campbell Creek (64) has an overall lower percentage of residential area and a much lower road density. The upstream part of the subbasin is predominantly undeveloped, whereas the lower part (near the sampling site) is heavily developed, residential land. The concentration of development appears to have had a negative effect on water quality, even though road density is comparatively low. The remaining subbasins (65, 67, 27) as well as the downstream subbasin (69) in Little Rabbit Creek are the most heavily developed, and all exceeded threshold values for all measured variables.

The initiation of a negative response of many invertebrate and water-chemistry variables appears to relate to road density. With the exception of subbasin 64 (see above), road densities greater than 3 miles per square mile appear to relate directly to PIA thresholds of 3 to 4 percent in a subbasin. The effect of riparian-zone width and composition on urban-stream function in Anchorage is currently under investigation by the Cook Inlet Basin NAWQA staff.



Campbell Creek (middle reach)



Chester Creek (downstream reach)

NEW PUBLICATIONS FROM THE COOK NAWQA

Glass, R.L., *Ground-Water Quality, Cook Inlet Basin, Alaska, 1999:* U.S. Geological Survey Water-Resources Investigations Report 01-4208, 58 p.

Glass, R.L., and Frenzel, S.A., *Distribution of Arsenic in Water and Streambed Sediments, Cook Inlet Basin, Alaska:* U.S. Geological Survey Fact Sheet FS-083-01, 4 p.

Kyle, R.E., and Brabets, T.P., *Water Temperature of Streams in the Cook Inlet Basin, Alaska, and Implications of Climate Change:* U.S. Geological Survey Water-Resources Investigations Report 01-4109, 24 p.

This newsletter was prepared by the Cook Inlet Basin study team. The purpose of the newsletter is to keep members of the Cook Inlet NAWQA liaison committee informed of our activities. The newsletter represents the views of the COOK NAWQA team and is intended for information purposes only. It is not intended for redistribution or publication, and should not be cited. If you would like your name removed from or a name added to the mailing list for this newsletter, or if you have any comments regarding this newsletter or our workplans, please contact project chief Steve Frenzel at (907)786-7107, or write to COOK NAWQA, U.S. Geological Survey, 4230 University Drive, Suite 201, Anchorage, AK 99508-4664, or send email to sfrenzel@usgs.gov

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